DUAL- BAND ANTENNA FOR MICROWAVE LEAKAGE DETECTOR AT 915MHz AND 2.45 GHz

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Abstract
This paper concentrates on studying, designing and manufacturing a dual-band antenna for microwave power leakage application. The proposed antenna is designed to support the dual-frequency bands at 915 MHz and 2.45GHz, by using dipole and coupled slot techniques. Antenna frequencies are defined by size of radiating element and coupled slot. The antenna was created as a microstrip patch on FR4 substrate with the size of 141 mm x 11 mm, thickness of 0.8 mm and relative permittivity of 4.3 using fed by a 50-Ω SMA connector. The measured return loss result at 915 MHz is -32.71 dB and -21.47 dB at 2.45 GHz which are in good agreement with the simulation at both frequencies. The proposed antenna has low profile, light weight, slim and inexpensive.

Keywords: antenna, dual-band, dipole, coupled slot, microstrip patch

Introduction

Microwave heating systems have been widely developed for industrial applications especially for food and agricultural products [1]. However, if the microwave oven is damaged or fabricated with substandard condition, it might have radiation hazard which results from leakage of microwave power [2]. Mostly, a microwave heating system is designed to operate at center frequencies of 915 MHz or 2.45 GHz which are in the industrial, scientific and medical (ISM) radio bands [3].

At present, a spectrum analyzer is applied to measure the leakage signal from microwave heating systems [4]. However, this measurement instrument is not convenient to use in an application that requires a lot of movement due to its weight. Also, it is relatively expensive and has excessive functions. Therefore, a microwave leakage detector is an alternative solution to verify the safety of the microwave heating system. In order to fabricate the microwave leakage detector, the antenna is an essential part that needs to be considered. If it is designed properly, it can reduce the complexity of the detector circuit.

In general, there are many techniques to achieve dual-band operation which have been published [5]-[8]. The dual-band antenna can be fabricated from composite structure that resonates at two different frequencies [5]-[6]. Although, the antenna design shows good performances, its structure is huge and thus, not very integrable. The most popular technique for producing a dual-band antenna is slot configuration on the radiating element [7]-[8]. In [7], a slot-coupled dipole antenna was introduced to make the antenna operate in dual-band. But its structure is too complex and difficult to fabricate because it was made from conductor plate with many coupled slot on dipole element.

In this paper, a dual-band antenna with a low profile of dipole element is proposed for microwave leakage detector application. The antenna is made from FR4 substrate by using coupled slot techniques with a simple configuration for creating the second resonant frequency and also, the proposed antenna allows easy modification of the return loss for matching. The methodology of the proposed antenna design will discuss in next section.

Antenna Design

The antenna composes of radiating element with length approximate 1/2 wavelength which is useful to define the first resonant frequency at 915MHz. In the same way, using coupled slot with length approximate 1/4 wavelength is the method to define second resonant frequency at 2.45 GHz.

The structure of the proposed dual-band antenna is shown in Figure 1. The antenna is fabricated on FR4 substrate which is an inexpensive material the thickness is 0.8 mm and relative permittivity is 4.3. Figure 2 illustrates the dimensions of the antenna which consists of a dipole element with the length L1 and a coupled slot with the length L2 which has a width W4. The distances between dipole patches are L3 and L4. The width of antenna and conductor patch is W1 and W2 respectively. The proposed antenna was simulated using Computer Simulation Technology (CST) that the antenna is fed by a 50 ohm. The overall dimensions of proposed antenna 141 x 11 mm^2 and the optimum size of the antenna is detailed in Table 1.

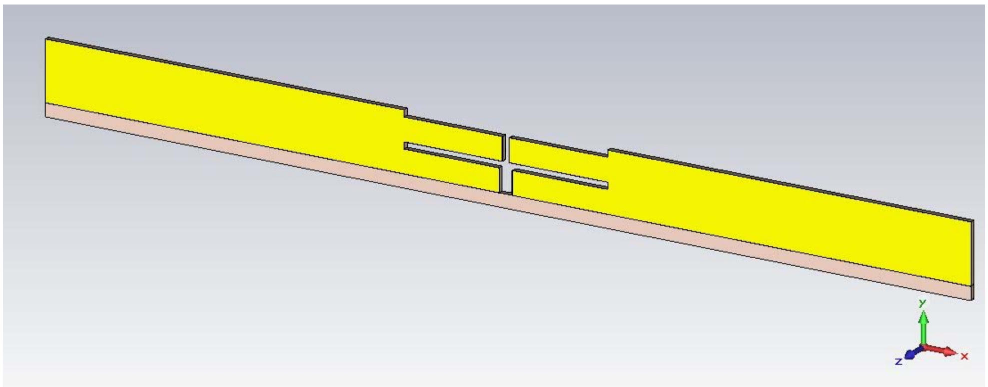

Figure 1 Structure of the proposed dual-band antenna (perspective view**)**

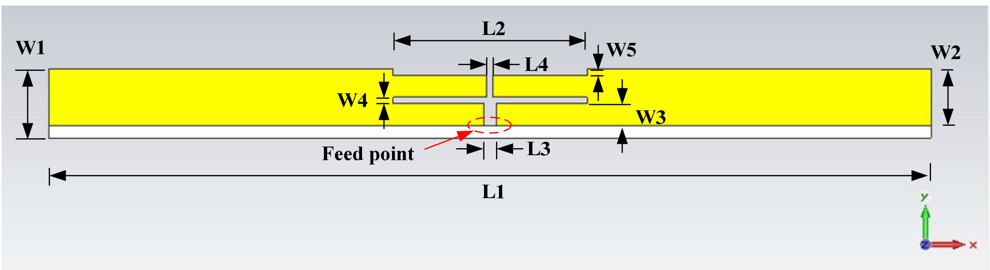

Figure 2 Dimensions of the proposed dual-band antenna (front view)

Table 1 The optimum antenna parameters

Parameter	Size(mm)	Parameter	Size(mm)
L1	141	W1	11
L2	31	W2	9
L3	2	W3	3.5
L4	1	W4,W5	1

Results and Discussion

Figure 3 shows the effect of conductor and substrate slot to the return loss of the antenna, where a conductor slot is the slot trimmed are copper plate on the top layer of FR4 only. In the same way, substrate slot is the slot trimmed through substrate element at same position as copper slot. From the result, it can be seen that the second resonant frequency will be shifted to the left when the antenna trimmed only on the conductor layer.

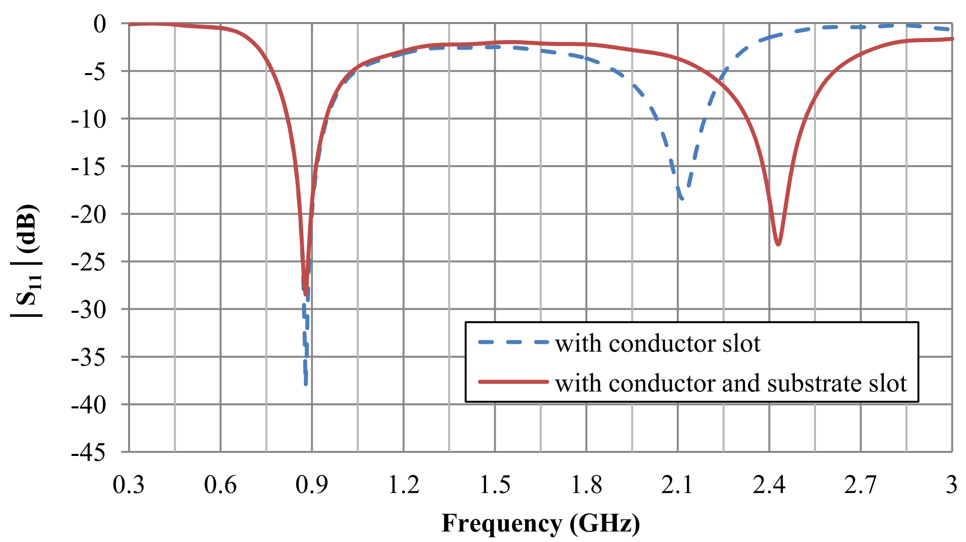

Figure 3 Simulated return loss of the proposed antenna coupled conductor slot and substrate slot

The length of antenna is parameter L1. When the value of L1 is decreased, both operating frequencies will be shifted to the left. This result is the fundamentals of basic calculation for the size of the antenna. When the length of the propose antenna becomes shorter, it will operate at the higher frequency. It can be seen from Figure 4 (left)

Therefore, the length of coupled slot, parameter L2, is introduced to control the second resonant frequency of the propose antenna. It can be seen from Figure 4 (right) that the second resonant frequency will be shifted to the right when L2 is increased. On the other hand the first resonant frequency will still remain unshifted. The behavior of these two parameters L1 and L2 were used for optimizing the performance of the propose antenna. Figure 5 shows the simulated result of 3D radiation patterns at 915 MHz (left) and 2.45 GHz (right) with antenna gain of 1.97 dBi and 4.56 dBi, respectively. The result shows that the radiation patterns of the proposed antenna is omni-directional at both frequencies.

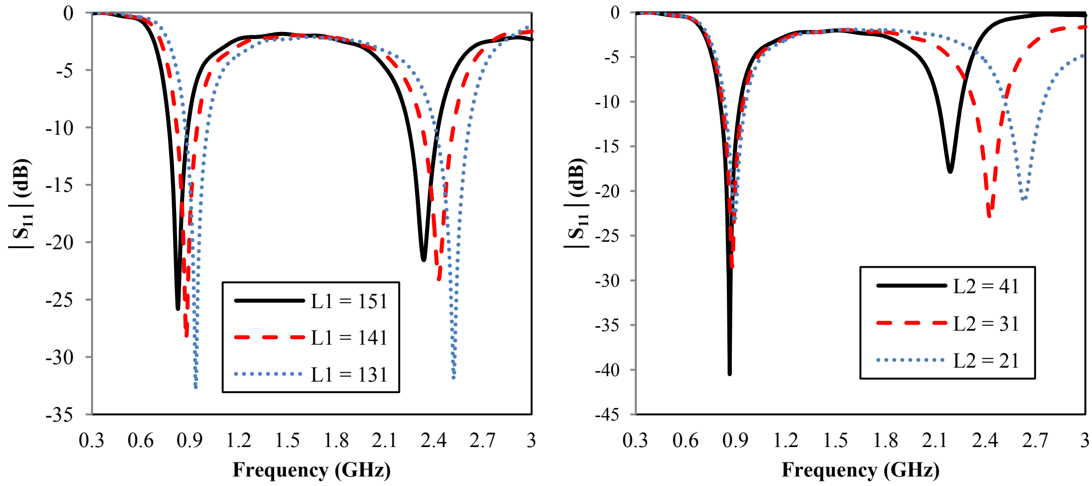

Figure 4 Simulated return loss of the proposed antenna for various values the parameters L1 (left) and parameters L2 (right)

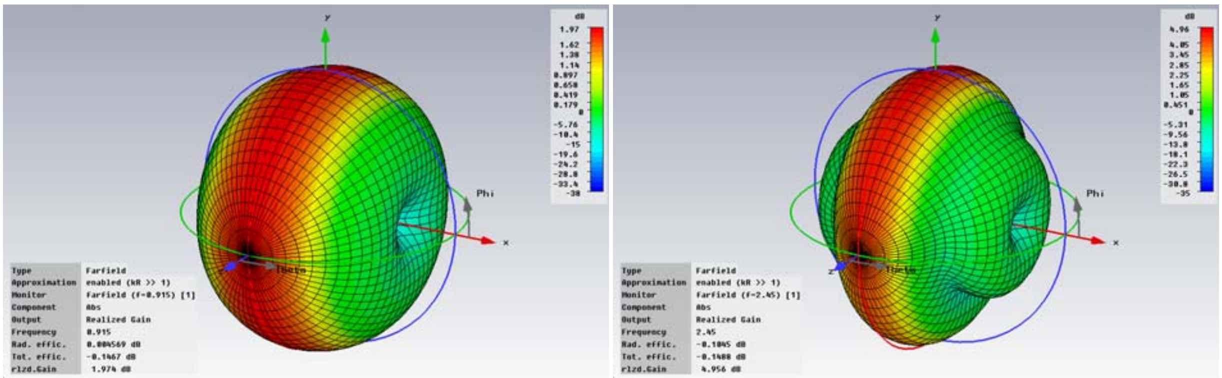

Figure 5 Simulated 3D radiation patterns at 915 MHz (left) and 2.45 GHz (right)

Figure 6 The propose dual-band antenna prototype

The propose dual-band antenna prototype is fed by a 50-Ω SMA connector, as shown in Figure 6. In this paper, Agilent N5242A PNA-X microwave network analyzer was used to measure the return loss of the proposed antenna prototype. The comparison of measured and simulated results of return loss is illustrated in the Figure 7. Both results are in good agreement in terms of return loss lower than -10 dB. The measured result at 915 MHz shows

S_{11} -32.71 dB with bandwidth of 166 MHz (835~1001) and at 2.45 GHz, S_{11} is -21.47 dB with the bandwidth 244 MHz (2347~2443).

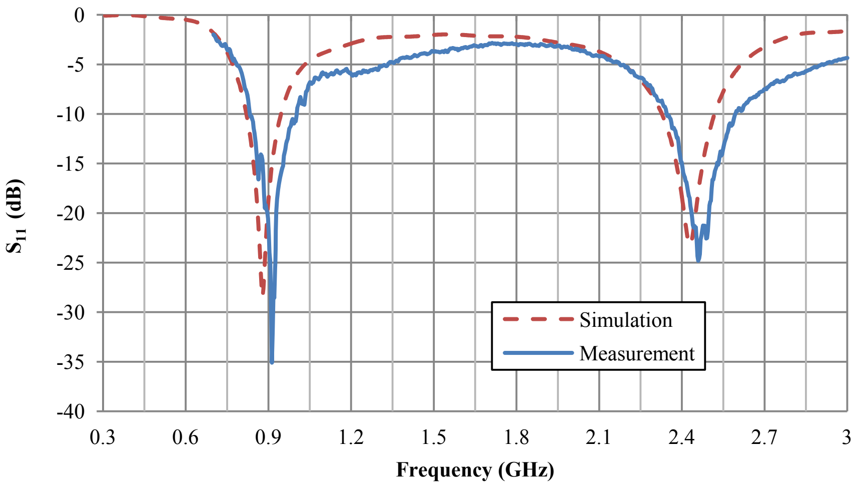

Figure 7 Comparison between simulated and measured return loss

Conclusion

The proposed simple dipole coupled slot antenna applied for microwave leakage detector can respond in dual band at 915 MHZ and 2.45 GHz. The antenna radiates omni-directional beam in both bands. The proposed antenna has been fabricated it showed good agreement of results from measurement and simulation. The measured S_{11} is lower than -10 dB. Despite measured result shifts a little from simulated result, but both results still have same tendency. The gain at 915 MHz is 1.97 dBi and at 2.45 GHz is 4.56 dBi respectively. The advantage of low profile design antenna allows easy optimization the resonant frequency for matching to 50 ohm of the SMA connector.

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References

1. M.S. Venkatesh, G.S.V. Raghavan (2005) An overview of dielectric properties measuring techniques. Canadian Biosystems Engineering 47:7.15-7.32.
1. M. Bangay, C. Zombolas (2004) Advanced measurements of microwave oven leakage. Australian Radiation Protection and Nuclear Safety Agency Conference paper.
2. Jonathan B. Leonard, Sally P. Shepardson (1992) Comparison of microwave and convective heating in rapid specimen preparation techniques for electron. IEEE MTT-S Digest 3:1263-1266.
3. Richard A. Tell (1978) Field-Strength measurements of microwave-oven leakage at 915 MHz. IEEE transactions on electromagnetic compatibility 20:341-346.
4. C. Phongcharoenpanich, R. Suwalak (2010) Dual-band RFID-reader antenna using annular plate with curved and rectangular slots. IEEE: 633-636.

5. M. I. Sabran, S.K.A. Rahim, A.Y.A. Rahman, T.A. Rahman, M.Z.M. Nor, Evizal (2011) Dual band diamond shaped antenna for RFID application. IEEE 10:979-982.
6. S. Jeon, Y. Yu, J. Choi (2006) Dual-band slot-coupled dipole antenna for 900MHz and 2.45 GHz RFID tag application. ELECTRONICS LETTERS 42:22
7. Xiaoang Li, Chao Li (2010) design of high gain multiple U-Slot microstrip patch antenna for wireless system. ICCP: 256-259.